PCT/AU00/01151

AU00/ 1151

REC'D 24 NOV 2000

WIPO PCT

Patent Office
Canberra

4

I, JONNE YABSLEY, ACTING TEAM LEADER EXAMINATION SUPPORT & SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PQ 3001 for a patent by THE UNIVERSITY OF SYDNEY filed on 21 September 1999.

COMMONWEALTH OF AUSTRALIA
AUSTRALIA
PATENT OFFICE

WITNESS my hand this
Twentieth day of November 2000

J R Yabsley

JONNE YABSLEY
ACTING TEAM LEADER
EXAMINATION SUPPORT & SALES

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Applicant:

THE UNIVERSITY OF SYDNEY

Invention Title:

A GRATING DESIGN

The invention is described in the following statement:

GRATING, METHOD OF WRITING THE GRATING AND DEVICES INCORPORATING SUCH GRATINGS

Field of the Invention

The present invention relates broadly to a grating structure, method of writing the grating structure and devices incorporating such gratings. The present invention will be described herein with reference to grating structures for non-linear group delay dispersion compensation. However, it will be appreciated that the invention does have broader applications, e.g. for engineering of phase response of a fibre Bragg grating device.

Background of the Invention

Grating structures are widely used in optical waveguides for example as filters or as compensators for linear group delay dispersion.

In many systems non-linear group delay dispersion, i.e. second and higher order group delay dispersion, plays a significant role. Therefore, it is desirable that a compensator structure be provided that can compensate for non-linear group delay dispersion in such systems.

Summary of the Invention

The present invention provides an optical waveguide which incorporates a sampled grating having a chirped sampling period.

The optical waveguide may be in the form of an optical fibre.

Alternatively, the optical waveguide may be in the form of a planar waveguide.

The present invention may alternatively be defined as providing a method of producing a grating structure in a photosensitive optical waveguide, the method comprising the step UV-inducing refractive index variations in the waveguide to produce a sampled grating structure, wherein the sampling period is chirped.

The device may comprise a circulator having a plurality of ports, the square reflection band filter being located at one of the ports for filtering the square amplitude narrow band optical signal from the input broad band optical signal entering the circulator at an input port; and the sampled grating structure having the chirped sampling period to compensate dispersion in the square reflection band filter located at another port of the circulator, the circulator further comprising an output port for outputting the dispersion compensated narrow band optical signal.

The invention has applications for both planar and cylindrical waveguides such as optical fibres.

Preferred forms of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Brief Description of the Drawings

Figure 1 shows a typical refractive index profile of a grating produced by UV-induced refractive index variations.

Figure 2 is a schematic drawing illustrating direct UV writing techniques.

Figure 3 is a schematic drawing illustrating interferometric UV writing techniques.

Figure 4 shows a refractive index profile of a sampled grating.

Figure 5 shows a refractive index profile of a grating embodying the present invention.

Figure 6 is a plot illustrating group delay dispersion of an apodised grating embodying the present invention.

Figure 7 shows an apodised refractive index profile of a grating embodying the present invention.

Figure 8 shows a plot illustrating group delay dispersion of a WDM channel.

Figure 9 is a schematic drawing of an optical device embodying the present invention.

Figure 10 shows a plot illustrating the resulting group delay dispersion of the optical device of Figure 9.

Detailed Description of the Preferred Embodiments

In Figure 1, a typical refractive index profile 10 of a grating produced by UV-induced refractive index variations in a photosensitive waveguide material is shown. The profile is substantially sinusoidal, with a spatial period Λ. For Bragg gratings, typical spatial periods will be of the order of parts of micrometers such that the Bragg condition is fulfilled for a particular wavelength. Typically, the wavelengths of optical signals utilised in optical devices are between 1200 and 1600 nm.

The refractive index profile 10 is achieved by utilising interference of UV light beams for UV-inducing the refractive index variations in a photosensitive material, either through direct writing techniques (see Figure 2) or interferometric techniques (see Figure 3).

In sampled gratings the amplitude of the e.g. sinusoidal refractive index variation is varied periodically, resulting in a refractive index profile 40 as illustrated in Figure 4. A typical sampling period length would be of the order of millimeters.

From the above it follows that whilst the spatial period of the grating, which is typically of the order of parts of micrometers, is a parameter which is experimentally difficult to control and/or manipulate, the sampling spatial period is experimentally relatively easy to control and/or manipulate.

As illustrated in Figure 5, the refractive index profile 50 of a sampled grating for which the sampling period has been chirped, the spatial period of the sinusoidal "envelope" 52 due to the sampling function decreases along the length of the grating. Importantly, the period of the grating Λ_2 remains constant throughout the entire length of the grating, thereby placing no special demands on the writing of the short period

structure. Only the relatively "long" period of the sampling function needs to be varied.

It is noted here that for illustrative purposes the sampling period lengths of Figure 5 have been set to higher values as they would typically be in a real system.

In Figure 6, the group delay dispersion 60 of an example sampled grating written with a chirped sampling period is shown. The sampling function is:

$$\left\{\cos\left[(K_0+\Delta K(z))z\right]+\cos\left[(K_0-\Delta K(z))z\right]\right\}/2=\cos\left[K_0 z\right]\cos\left[\Delta K(z)z\right].$$

Furthermore, an apodisation function has been applied in the form of a function which monotonically decreases from a starting value at the beginning of the grating to zero at the end of the grating. The refractive index profile 62 of the resulting grating is shown in Figure 7.

It will be appreciated that the group delay dispersion shown in Figure 6 can be utilised to compensate for non-linear group delay dispersion, for example for non-linear group delay dispersion in a WDM channel.

In Figure 8, the group delay dispersion 80 of a WDM channel is illustrated. The group delay dispersion is substantially inverse to the group delay dispersion 60 of the example grating structure (see Figure 6) and it will be appreciated by a person skilled in the art that through appropriate selection of the sampling function and apodisation function, group delay dispersion in WDM channels can be compensated using a sampled grating for which the sampling period has been chirped.

In Figure 9, an optical device 90 comprises a circulator 92 having a sampled grating structure 91 with a chirped sampling period at one port 94 and a grating filter 96 optimised for "square" reflection band amplitude response at another port 98. An incoming broad band optical signal 100 entering the circulator at an input port 102 will initially propagate to the grating filter 96, of which a narrow band signal (not shown) within the square

reflection band is reflected back into the circulator 92. The narrow band signal is then reflected at the sampled grating 91 having the chirped sampling period, whereby an output signal 106 leaving the circulator 92 at an output port 108 will be a narrow band optical signal with substantially zero group delay dispersion within the square-shaped amplitude "channel". In other words, the group delay is substantially constant within the square-shaped amplitude channel, as shown in Figure 10, portion 110 of graph 112.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

For example, apodisation functions other than the one described could be used during the writing of the sampled grating with a chirped sampling period.

The Claims Defining the Invention are as Follows:

1. An optical waveguide incorporating a sampled grating having a chirped sampling period.

2. A method of producing a grating structure in a photosensitive optical waveguide, the method comprising the step of:

- UV-inducing refractive index variations in the waveguide to produce a sampled grating structure, wherein a sampling period of the refractive index variation is chirped.

3. An optical device comprising a sampled grating structure which has been produced with a chirped sampling period.

4. A method of compensating group delay dispersion in an optical waveguide utilising a sampled grating structure which has been produced with a chirped sampling period.

5. A group delay dispersion compensator comprising a sampled grating structure which has been produced with a chirped sampling period.

6. A method of producing a zero dispersion WDM channel, the method comprising the steps of:

- utilising a square reflection band filter to filter a narrow band optical signal from an input broad band optical signal; and
- utilising a sampled grating structure having a chirped sampling period to compensate dispersion of the reflection band filter.

7. A device for producing a zero dispersion WDM channel, the device comprising:

- a square reflection band filter for filtering a narrow band optical signal from an input broad band optical signal; and
- a sampled grating structure having a chirped sampling period to compensate dispersion of the square reflection band filter.

Dated this 21st day of September 1999

The University of Sydney

By their Patent Attorneys

GRIFFITH HACK

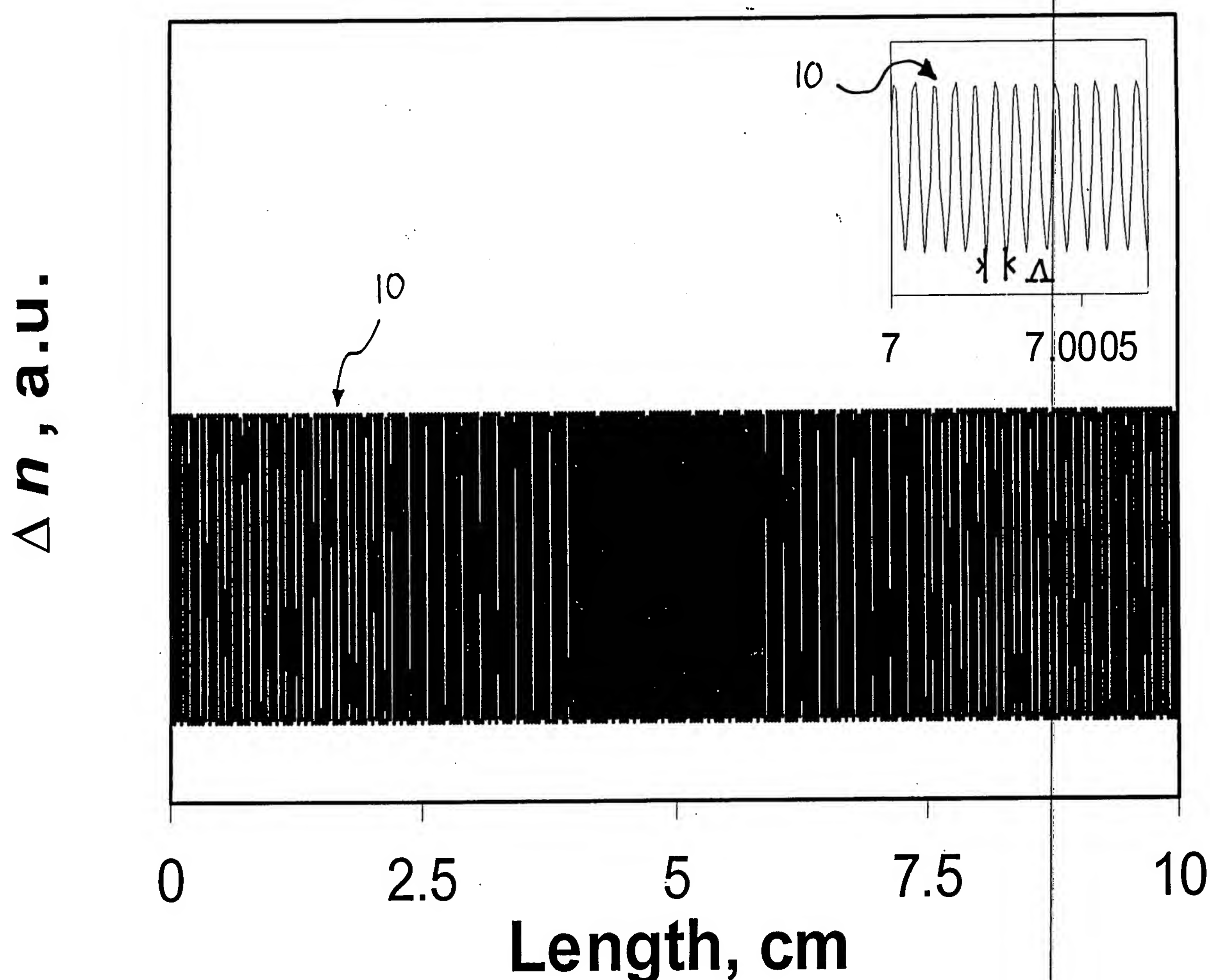


FIG 1

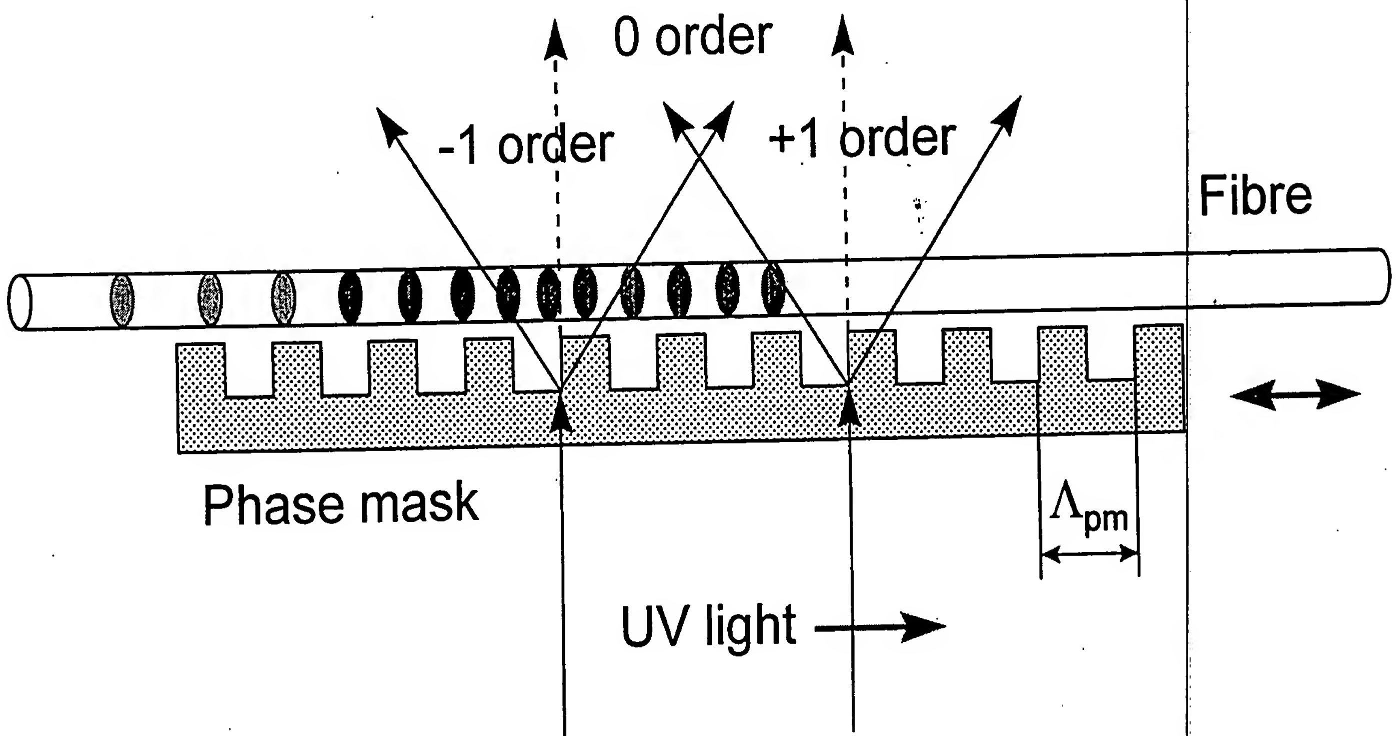


FIG 2

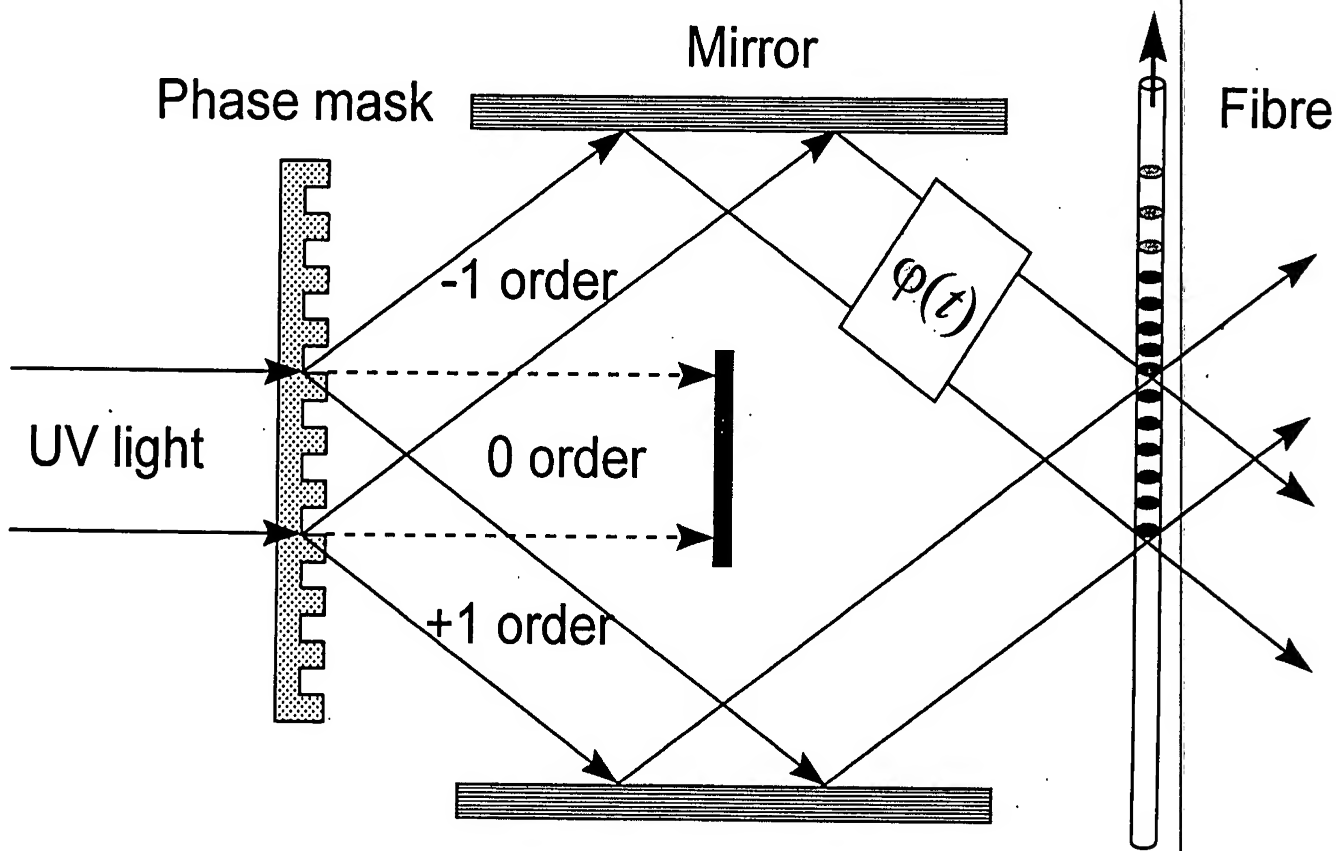

Mirror
Phase mask
Fibre
-1 order
UV light
0 order
+1 order
$\varphi(t)$

FIG 3

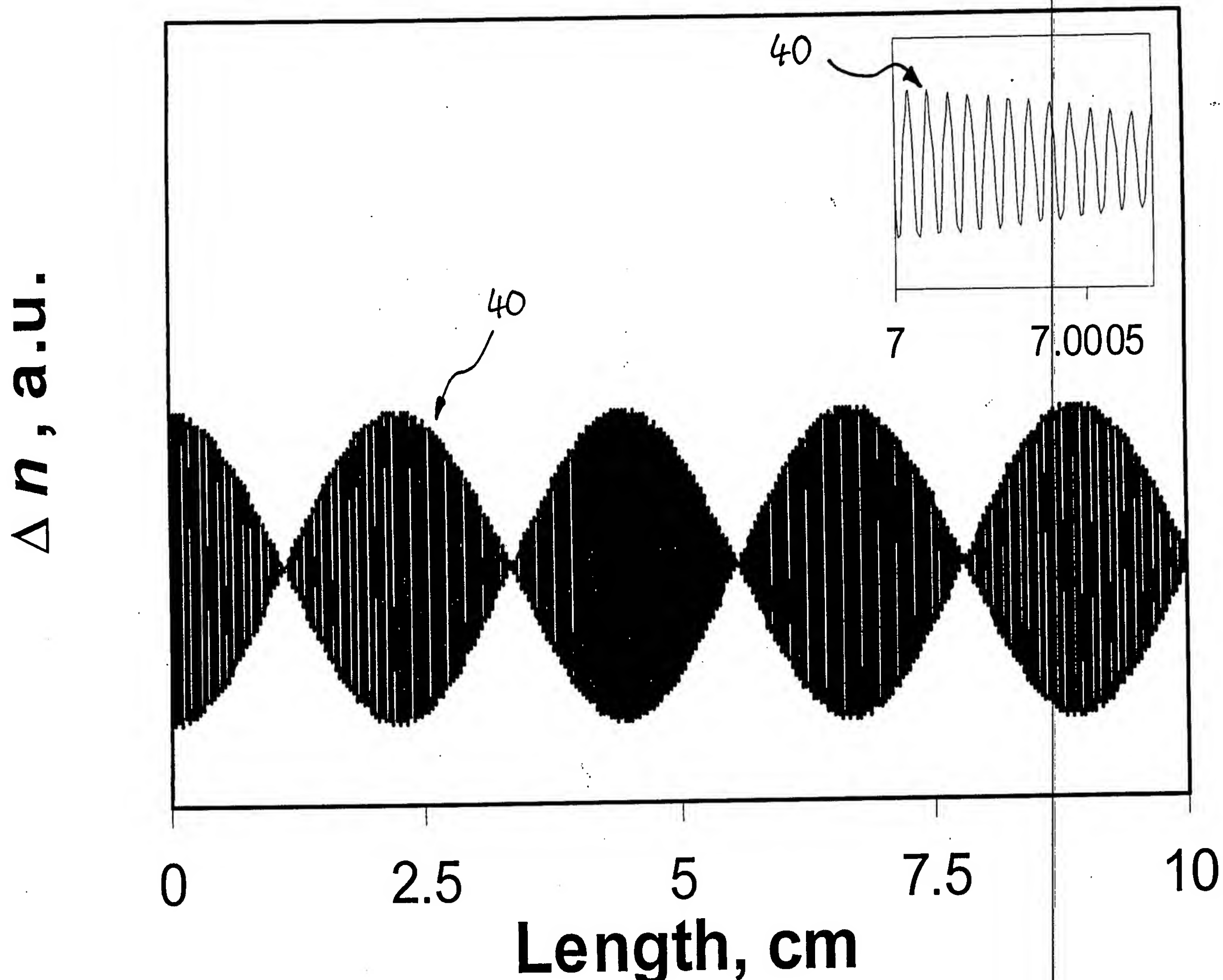


FIG 4

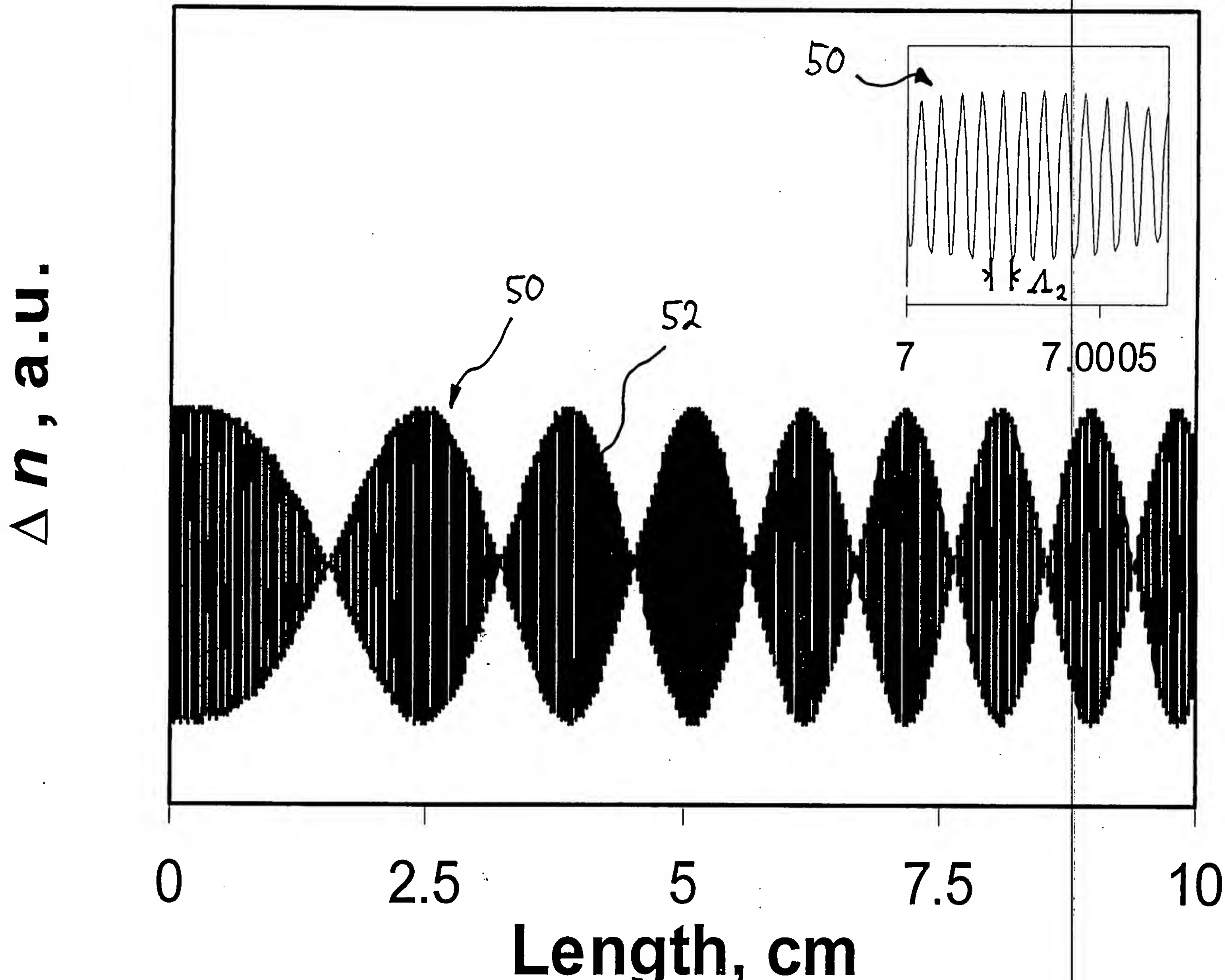


FIG 5

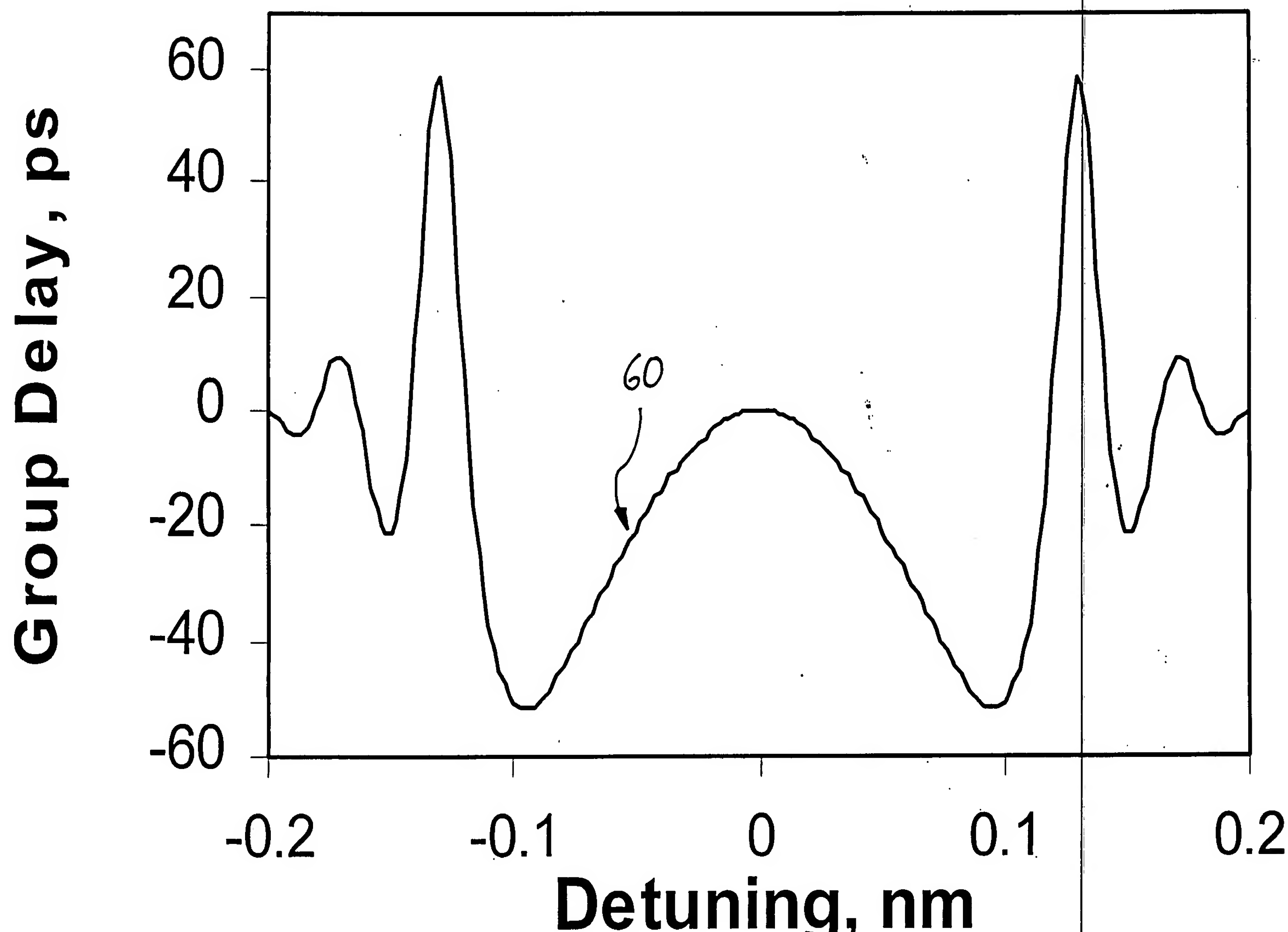


FIG 6

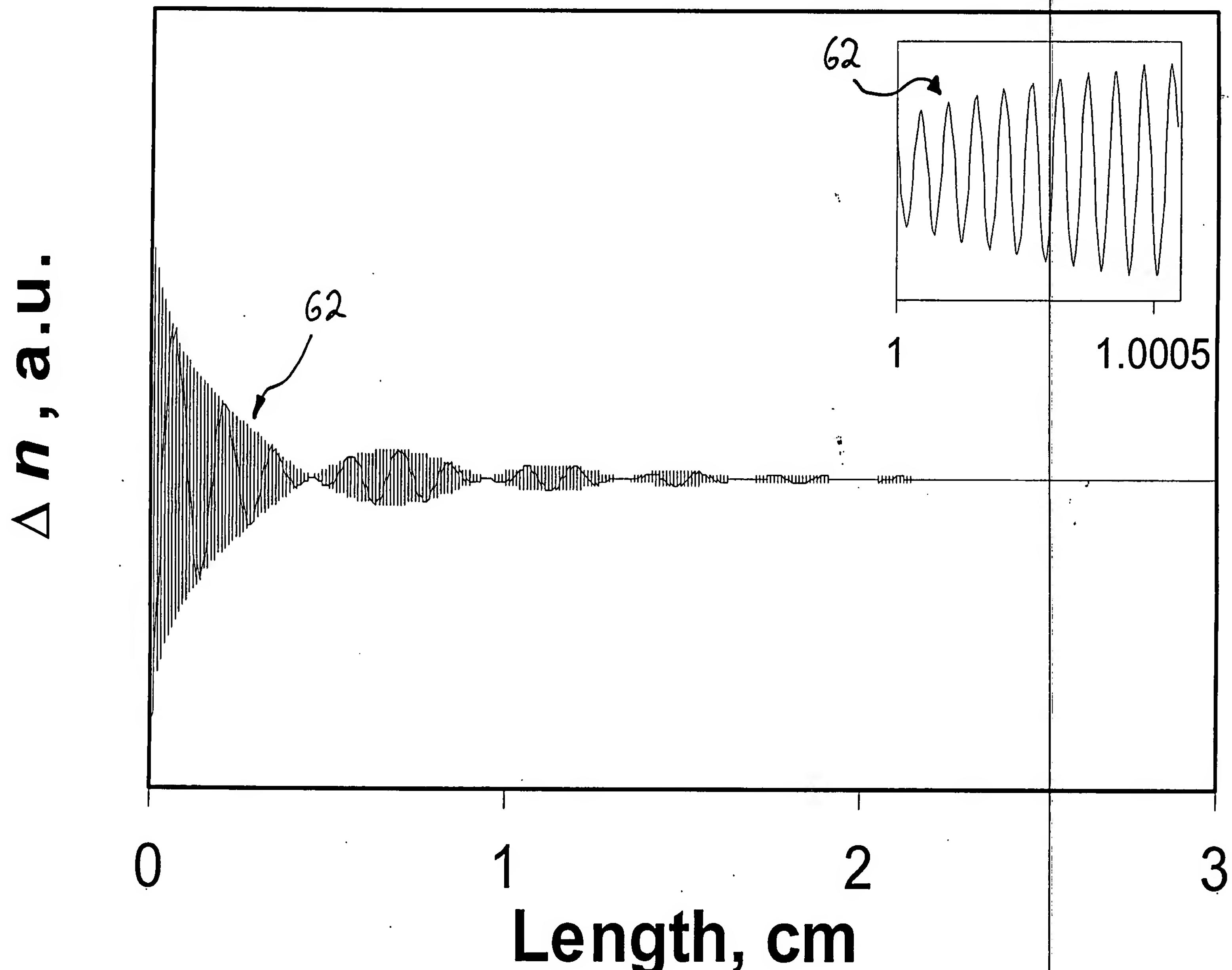


FIG 7

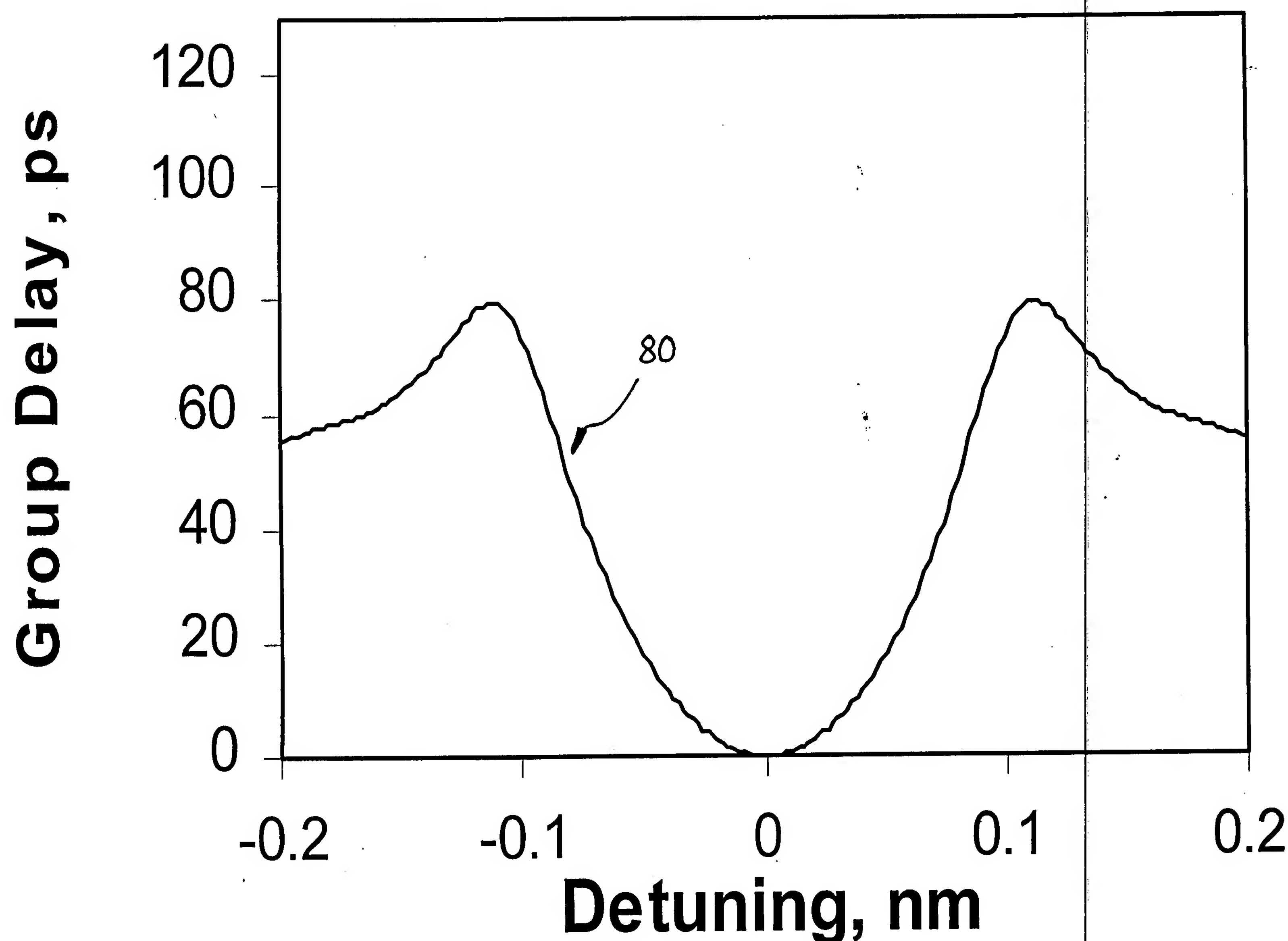


FIG 8

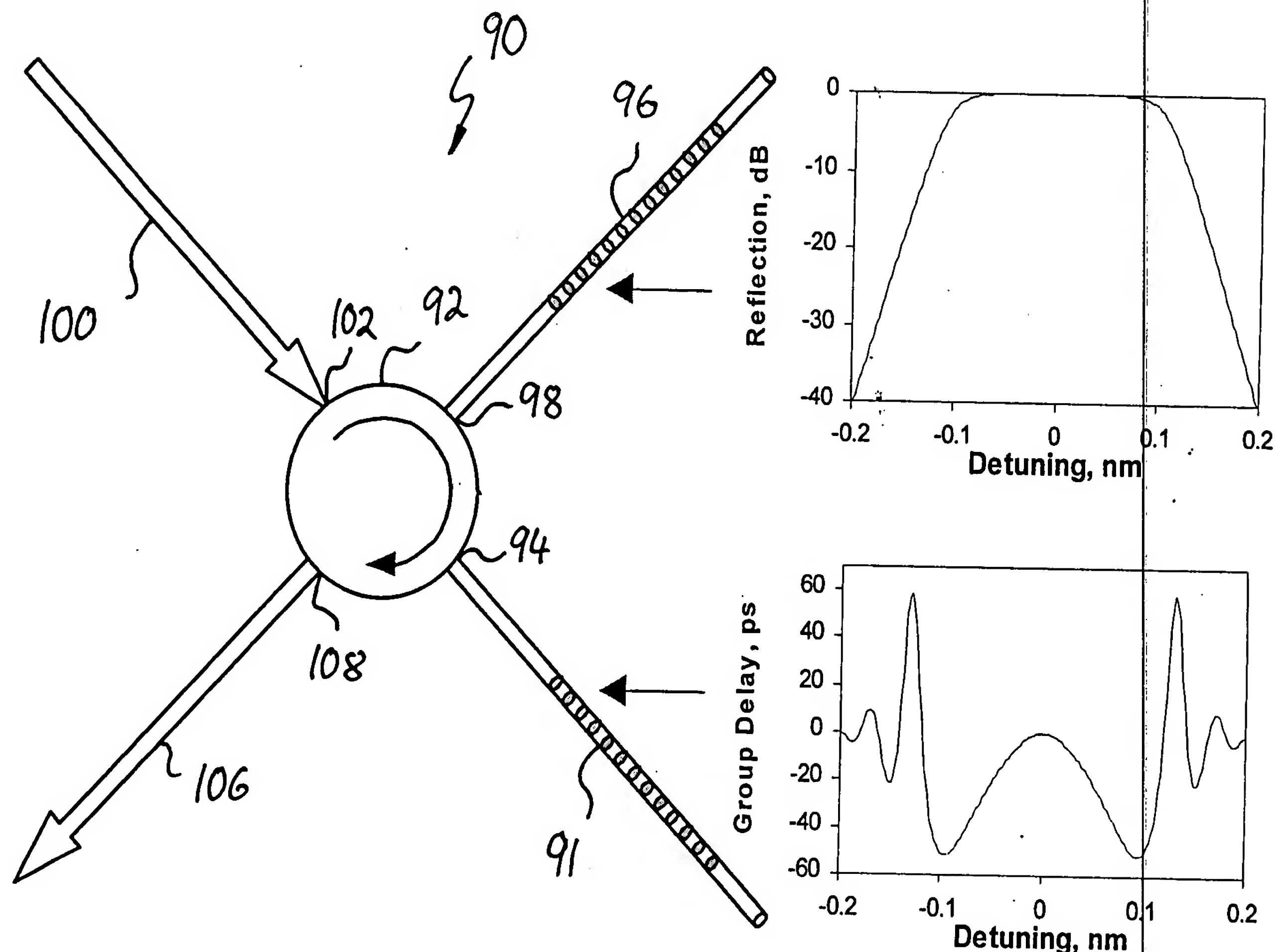
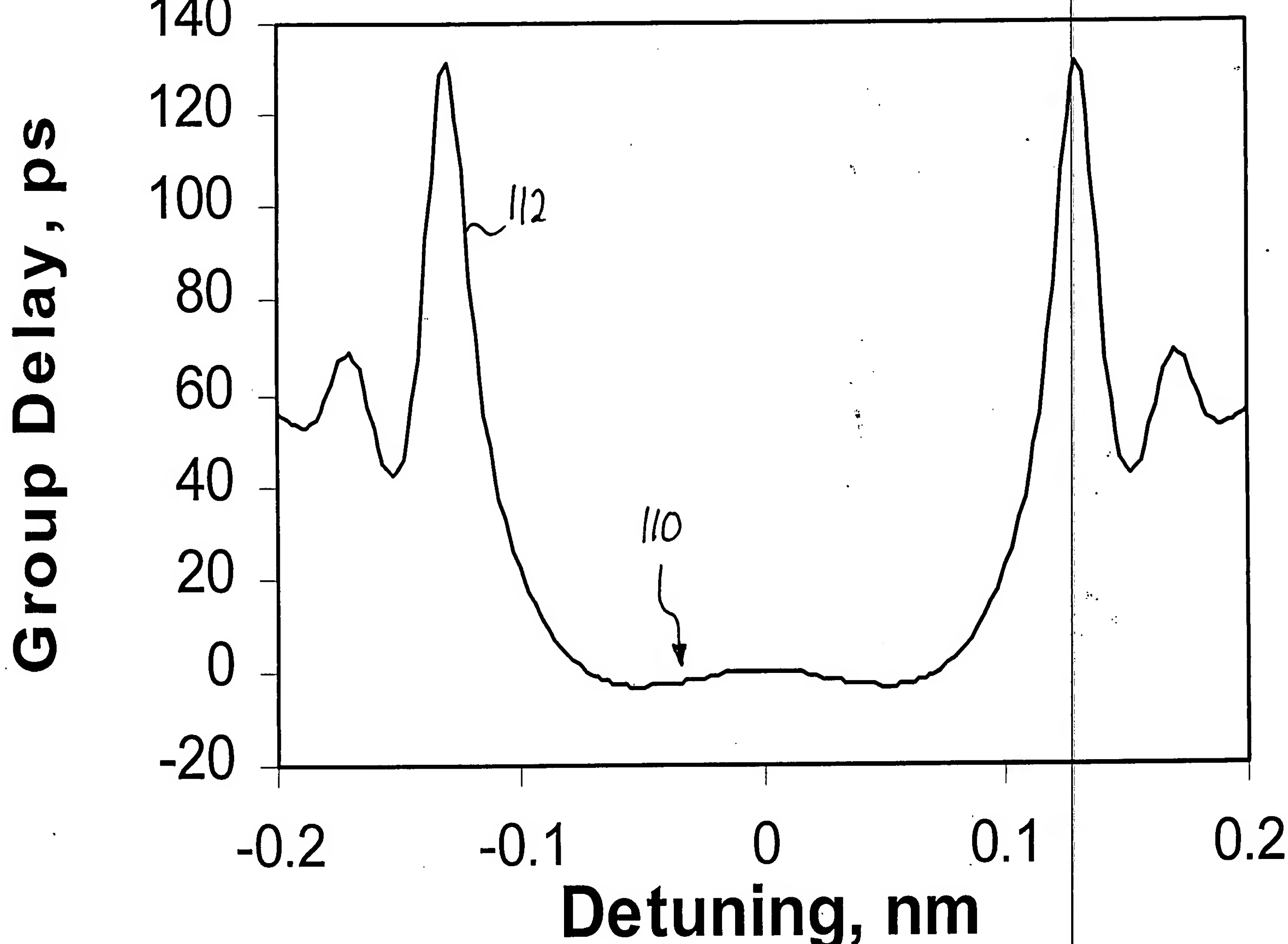

90
96
98
92
102
100
94
108
106
91
Reflection, dB
0
-10
-20
-30
-40
-0.2
-0.1
0
0.1
0.2
Detuning, nm
Group Delay, ps
60
40
20
0
-20
-40
-60
-0.2
-0.1
0
0.1
0.2
Detuning, nm

FIG 9



Group Delay, ps
140
120
100
80
60
40
20
0
-20
-0.2
-0.1
0
0.1
0.2
Detuning, nm
112
110

FIG 10